13-1

解：

（1）$E_{0*}=\sqrt{U_*^2+(I_*\cdot x_{S*})^2}=\sqrt{2}=1.414$

$$\Delta U\%=\frac{E_{0*}-U_*}{U_*}\times 100\%=41.4\%$$

$$\delta=\arctan\frac{I_*\cdot x_{S*}}{U_*}=45^\circ$$

（2）$\dot{I}_*=0.9$

$\theta=31.79^\circ$

$$\begin{aligned}\dot{E}_{0*}&=\dot{U}_*+j\dot{I}_*\cdot x_{S*}\\&=1+j0.9\angle-31.79^\circ\\&=1.474+j0.765\\&=1.66\angle 27.43^\circ\end{aligned}$$

$\therefore E_{0*}=1.66\qquad \delta=27.43^\circ$

$$\Delta U\%=\frac{1.66-1}{1}\times 100\%=66\%$$

（3）$\dot{I}_*=0.9$

$\theta=31.79^\circ$

$$\begin{aligned}\dot{E}_{0*}&=\dot{U}_*+j\dot{I}_*\cdot x_{S*}\\&=1+j0.9\angle 31.79^\circ\\&=0.526+j0.765\\&=0.928\angle 55.49^\circ\end{aligned}$$

$\therefore E_{0*}=0.928\qquad \delta=55.49^\circ$

$$\Delta U\%=\frac{0.928-1}{1}\times 100\%=-7.2\%$$

13-2

解：

（1）设$\dot{U}_{N*}=1\angle 0^\circ$　则$\dot{I}_*=1\angle 0^\circ$

$$\dot{U}_{N*}+j\dot{I}_*\cdot x_{q*}=1.0+j0.6$$

$$\delta=\arctan\frac{0.6}{1}=30.96^\circ$$

$$\varphi=\theta+\delta=0^\circ+30.96^\circ=30.96^\circ$$

$$I_{d*}=I\cdot\sin\varphi=0.514$$

$$I_{q*}=I\cdot\cos\varphi=0.857$$

$$\begin{aligned}E_{0*}&=\dot{U}_*\cdot\cos\delta_N+I_{d*}\cdot x_{d*}\\&=1\times\cos 30.96^\circ+0.514\\&=1.372\end{aligned}$$

$$\Delta U\%=\frac{1.372-1}{1}\times 100\%=37.2\%$$

$$\begin{aligned}P_{M*}&=\frac{E_{0*}\cdot U_*}{x_{d*}}\cdot\sin\delta+\frac{U_*^2(x_{d*}-x_{q*})}{2x_{d*}\cdot x_{q*}}\sin 2\delta\\&=1.372\sin\delta+0.333\sin 2\delta\end{aligned}$$

（2）设$\dot{U}_{N*}=1\angle 0^\circ$　则$\left|\dot{I}_*\right|=0.9$

$$\dot{I}_*=0.765-j0.474=0.9\angle -31.79^o$$

$$\dot{U}_{N*}+j\dot{I}_*\cdot x_{q*}=1.284+j0.459$$

$$\delta=\arctan\frac{0.459}{1.284}=19.67^\circ$$

$$\varphi=\theta+\delta=31.79^\circ+19.67^\circ=51.46^\circ$$

$$I_{d*}=I\cdot\sin\varphi=0.704$$

$$I_{q*} = I \cdot \cos\varphi = 0.561$$

$$E_{0*} = \dot{U}_* \cdot \cos\delta_N + I_{d*} \cdot x_{d*}$$
$$= 1 \times \cos 19.67^\circ + 0.704$$
$$= 1.646$$
$$\Delta U\% = \frac{1.646 - 1}{1} \times 100\% = 64.6\%$$

$$P_{M*} = \frac{E_{0*} \cdot U_*}{x_{d*}} \cdot \sin\delta + \frac{U_*^2 (x_{d*} - x_{q*})}{2x_{d*} \cdot x_{q*}} \sin 2\delta$$
$$= 1.646 \sin\delta + 0.333 \sin 2\delta$$

（3）设$\dot{U}_{N*} = 1\angle 0^\circ$ 则$\left|\dot{I}_*\right| = 0.9$

$$\dot{I}_* = 0.765 + j0.474 = 0.9\angle 31.79^\circ$$

$$\dot{U}_{N*} + j\dot{I}_* \cdot x_{q*} = 0.716 + j0.459$$

$$\delta = \arctan\frac{0.459}{0.716} = 32.66^\circ$$

$$\varphi = \theta + \delta = 32.66^\circ - 31.79^\circ = 0.87^\circ$$

$$I_{d*} = I \cdot \sin\varphi = 0.014$$

$$E_{0*} = \dot{U}_* \cdot \cos\delta_N + I_{d*} \cdot x_{d*}$$
$$= 1 \times \cos 32.66^\circ + 0.014$$
$$= 0.856$$
$$\Delta U\% = \frac{0.856 - 1}{1} \times 100\% = -14.4\%$$

$$P_{M*} = \frac{E_{0*} \cdot U_*}{x_{d*}} \cdot \sin\delta + \frac{U_*^2 (x_{d*} - x_{q*})}{2x_{d*} \cdot x_{q*}} \sin 2\delta$$
$$= 0.856 \sin\delta + 0.333 \sin 2\delta$$

13-3

解：

（1）$U_\phi = \frac{U_N}{\sqrt{3}} = \frac{105000}{\sqrt{3}} = 6.06\text{KV}$

$I_\phi = I_l = \frac{S_N}{\sqrt{3}U_N} = \frac{24000}{\sqrt{3}\times 10.5} = 1.32\text{KA}$

故 $Z_N = \frac{U_\phi}{I_\phi} = \frac{6.06}{1.32} = 4.6\Omega$

所以 $x_{d*} = \frac{x_d}{Z_N} = \frac{5}{4.6} = 1.09 \quad x_{q*} = \frac{x_q}{Z_N} = \frac{2.76}{4.6} = 0.6$

$$P_* = \frac{E_{0*}\cdot U_*}{x_{d*}}\cdot\sin\delta + \frac{U_*^2(x_{d*}-x_{q*})}{2x_{d*}\cdot x_{q*}}\sin 2\delta$$
$$= 1.376\sin\delta + 0.375\sin 2\delta$$

（2）$P_* = \frac{20MKVA}{24MKVA} = 0.833$

解方程 $1.376\sin\delta + 0.375\sin 2\delta = 0.833$

得 $\delta = 23.8^\circ$

（3）$I_{d*} = \frac{E_{0*} - U_*\cdot\cos\delta}{x_{d*}} = \frac{1.5 - 1\cdot\cos 23.8^\circ}{1.09} = 0.537$

$I_{q*} = \frac{U_*\cdot\sin\delta}{x_{q*}} = \frac{1\cdot\sin 23.8^\circ}{0.6} = 0.673$

$I_* = \sqrt{I_{d*}^2 + I_{q*}^2} = 0.86$

$\varphi = \arctan\frac{I_{d*}}{I_{q*}} = 38.57^\circ$

$\theta = \varphi - \delta = 14.77^\circ$

所以 $Q = S_N\cdot U_* I_*\sin\theta = 24\cdot 1\cdot 0.86\cdot\sin 14.77^\circ = 5.256\text{MVA}$

$Q_*$=5.256/24=0.219

（4）$\frac{dP_*}{d\delta} = 1.376\cos\delta + 0.75\cos 2\delta = 0$

因为$1<\cos\delta<1$，解这个方程得$\cos\delta=0.3842$

即 $\delta=67.4^\circ$

所以$\sin\delta=0.923$　　$\sin 2\delta=0.71$

故$P_{\max *}=1.376\times0.923+0.375\times0.71=1.54$

$P_{max}=1.54\times24\mathrm{MW}=36.96\mathrm{MW}$

13-4

解：

（1）$\dot{E}_{0*}=\dot{U}_{*}+jI_{*}\cdot x_{s*}$ ，$\dot{U}_{*}=jI_{*}\cdot x_{s*}+\dot{E}'_{0*}$

所以$\dot{E}'_{0*}=2\dot{U}_{*}-\dot{E}_{0*}$

令$\dot{U}_{*}=1\angle0^\circ$，$P_{*}=0.5$

则$P_{*}=\dfrac{E_{0*}\cdot U_{*}}{x_{s*}}\sin\delta=0.5\Rightarrow\delta=24.62^\circ$

所以$\dot{E}_{0*}=\dot{U}_{*}+jI_{*}\cdot x_{s*}=1.2\angle24.62^\circ$

$\dot{E}'_{0*}=2\dot{U}_{*}-\dot{E}_{0*}=2-1.2\angle24.62^\circ=1.038\angle-28.81^\circ$

（2）解法一：

$P_{*}=\dfrac{E_{0*}\cdot U_{*}}{x_{s*}}\sin\delta=0.5$

$E_{0*}=1.1$时$\dot{E}'_{0*}=1.038$不变

$\varphi=\arcsin(\dfrac{1}{1.1\times1.04})=61.24^\circ$

$U_0=0.5\sqrt{E_0^2+E_0'^2-2\times E_0\times E_0'\times\cos(180-\varphi)}=0.92$

解法二：

由题意：

$\begin{cases} E_{01*}U_*\sin\delta_1 = 0.5 \\ E_{02*}U_*\sin\delta_2 = 0.5 \end{cases}$，可推出：$\begin{cases} \sin\delta_1 = \dfrac{0.5}{E_{01*}U_*} = \dfrac{0.5}{1.1U_*} \\ \sin\delta_2 = \dfrac{0.5}{E_{02*}U_*} = \dfrac{0.5}{1.038U_*} \end{cases}$

另一方面，根据余弦定理有：

$\begin{cases} {E_{01*}}^2 + {U_*}^2 - 2E_{01*}U_*\cos\delta_1 = {I_*}^2 \\ {E_{02*}}^2 + {U_*}^2 - 2E_{02*}U_*\cos\delta_2 = {I_*}^2 \end{cases}$，可提出：${E_{01*}}^2 - {E_{02*}}^2 = 2U_*(E_{01*}\cos\delta_1 - E_{02*}\cos\delta_2)$

代入相应的数据可得：$U_*$=0.92 或者 $U_*$=0.544，考虑到稳定度，取 $U_*$=0.92。

13-6

解：

设$\dot{U}_* = 1\angle 0^\circ \quad \dot{I}_{D*} = 0.8 + j0.6$

$\dot{I}_* = -0.8 - j0.6$

$U_* + jI_*x_{q*} = 1.36 - j0.48 = 1.44\angle -19.44^\circ$

故$\delta = -19.4^\circ$

$\theta = \arccos 0.8 = 36.9^\circ$

所以$I_{d*} = I_*\sin(\theta - \delta) = 0.832$

$E_{0*} = U_*\cos\delta + I_{d*}\cdot x_{d*} = 1\cdot\cos(-19.4^\circ) + 0.832\times 1 = 1.77$

所以该电动机在过励状态下运行。